CHAPTER 3

ELECTRONIC IMAGING

With the evolution of electronic imaging, the technology involved today in the creation, manipulation, and distribution of images allows photographers to perform functions that they only dreamed of a decade ago. Procedures that once took hours or even days in the conventional darkroom can now be accomplished within minutes under normal room lights and without getting your hands wet. With the electronic medium, images may be created, modified, and enhanced, The end product is limited only by your imagination. Several distinct advantages of electronic imaging as compared to conventional photography are in use today. These advantages are as follows:

- It saves the time required in conventional development and printing.
- It saves money by eliminating direct and indirect costs related to developing and printing photographs.
- It is environmentally friendly.
- It can be viewed immediately.
- Images can be transmitted instantly and rapidly using standard telephone lines.

Electronic imaging used in the Navy today ranges from capturing and processing an image through an electronic medium to conventional silver-halide technology and electronic processing by way of a hybrid system. Because of the dynamic advances in this growing field, this chapter is intended only as a brief overview of the basic principles and applications of electronic imaging. To be prepared for this fascinating technology, you must become familiar with computer systems, electronic imaging, and the equipment used to create digital images.

BASIC COMPUTER FUNDAMENTALS

Computers are often compared to people since both have the ability to accept information, work with it, store it, retrieve it, and provide information output. The primary difference is that people have the ability to perform all of these actions independently without outside assistance. People also think and control their own actions. The computer, however, requires a program (a predefmed set of instructions) to accomplish an assigned task. People receive information in several different forms, such as eyes, ears, nose, mouth, and even sensory nerves. Our brain receives and accepts this information, works with it in some manner, and then stores it somewhere in the back of our mind (memory) for future use. If information at the time requires immediate attention, our mind directs us to respond with words or actions. Likewise, the brain of a computer is the central processing unit (CPU). The CPU is designed to do basically the same thing; that is, it receives information (input data), works with this information (processes data), and transmits this information (output data) to some form of output media.

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Computers are incapable of independent thought or action; they can do nothing more than perform the instructions given to them. Computers simply follow a set of instructions stored internally (called a program) and process the input data. Then when all the steps are followed properly, the computer provides an end result that you can work with.

The computers used in electronic imaging are general-purpose digital computers. These general-purpose computers are capable of performing operations, such as word processing, graphic applications, and spread sheet because they can store a wide variety of programs in internal storage.

COMPONENTS OF A DIGITAL COMPUTER

Components, or tools, of a computer system are grouped into two categories: HARDWARE and SOFTWARE. Hardware consists of the machines that comprise a computer system, such as all the mechanical, electrical, electronic, and magnetic devices within the computer itself and all related PERIPHERAL devices. The peripheral devices consist of items, such as a keyboard, magnetic tape unit, mouse, scanner, printer, and so on. The software items are programs and operating aids written so the computer can process data. The manufacturer supplies much of the initial software for a particular computer. This software is known as SYSTEMS SOFTWARE. Systems software is designed for broad general use. Examples of systems software are DOS (disk operating system) for IBM compatible computers and System 7 for Apple computers. Software designed to meet a specific requirement or purpose is called APPLICATION SOFTWARE. Examples of application software are *WordPerfect, Lotus 1-2-3,* and *Adobe Photoshop.*

FUNCTIONAL UNITS OF A COMPUTER SYSTEM

Digital computer systems consist of three distinct units. These units are as follows:

- Input unit
- Central Processing unit
- Output unit

These units are interconnected by electrical cables to permit communication between them. This allows the computer to function as a system.

Input Unit

A computer must receive both data and program statements to function properly and be able to solve problems. The method of feeding data and programs to a computer is accomplished by an input device. Computer input devices read data from a source, such as magnetic disks, and translate that data into electronic impulses for transfer into the CPU. Some typical input devices are a keyboard, a mouse, or a scanner.

Central Processing Unit

The brain of a computer system is the central processing unit (CPU). The CPU processes data transferred to it from one of the various input devices. It then transfers either an intermediate or final result of the CPU to one or more output devices. A central control section and work areas are required to perform calculations or manipulate data. The CPU is the computing center of the system. It consists of a control section, an arithmetic-logic section (fig. 3-1), and an internal storage section (main memory). Each section within the CPU serves a specific function and has a particular relationship with the other sections within the CPU.

CONTROL SECTION.—The control section directs the flow of traffic (operations) and data. It also maintains order within the computer. The flow of control is indicated by dotted arrows in figure 3-1. The control section selects one program statement at a time from the program storage area, interprets the statement, and sends the appropriate electronic impulses to the arithmetic-logic and storage sections so they can carry out the instructions. The control section does not perform actual processing operations on the data. The control section instructs the input device on when to start and stop transferring data to the input storage area. It also tells the output device when to start and stop receiving data from the output storage area.

ARITHMETIC-LOGIC SECTION.—The arithmetic-logic section performs arithmetic operations, such as addition, subtraction, multiplication, and division. Through internal logic capability, it tests various conditions encountered during processing and takes action based on the result. As indicated by the solid arrows in figure 3-1, data flows between the arithmetic-logic section and the internal storage section during processing. Specifically, data is transferred as needed from the storage section to the arithmetic-logic section, processed, and returned to internal storage. At no time does processing take place in the storage section. Data maybe transferred back and forth between these two sections several times before processing is completed. The results are then transferred from internal storage to an output device, as indicated by the solid arrow in figure 3-1.

INTERNAL STORAGE SECTION.—The internal storage section is sometimes called primary storage, main storage, or main memory, because this section functions similar to our own human memory.

The storage section serves four purposes; three relate to retention (holding) of data during processing. First, as indicated by the solid arrow (fig. 3-1), data is transferred from an input device to the INPUT STORAGE AREA where it remains until the computer is ready to process it. Second, a WORKING STORAGE AREA ("scratch pad" memory) within the storage section holds both the data being processed and the intermediate results of the arithmetic-logic operations. Third, the storage section retains the

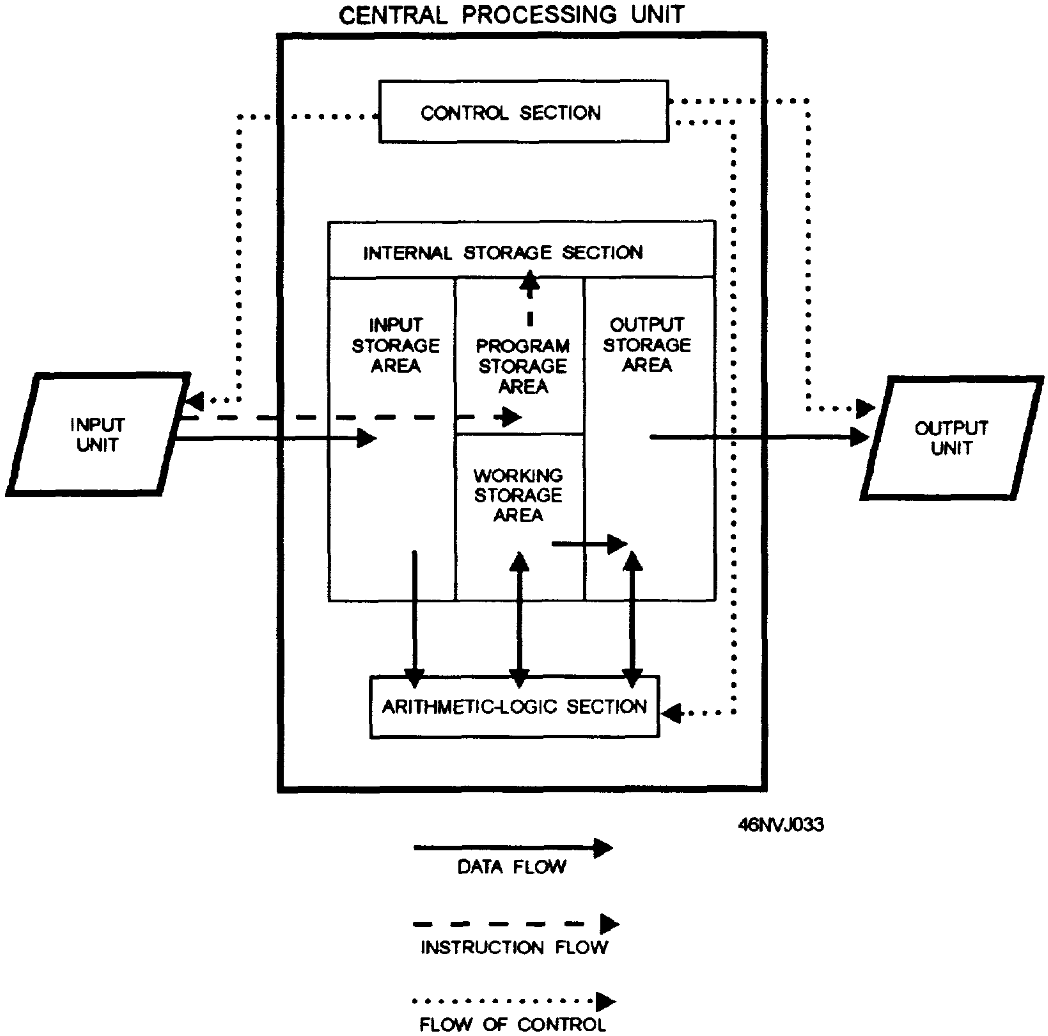

Figure 3-1.—Sections of a CPU.

processing results in the OUTPUT STORAGE AREA. From there the processing results can be transferred to an output device. The fourth storage section, the PROGRAM STORAGE AREA, contains the program statements transferred from an input device to process the data. Please note that the four areas (input, working storage, output, and program storage) are NOT fmed in size or location but are determined by individual program requirements.

Output Unit

As program statements and data are received by the CPU from an input device, the results of the processed data are sent from the CPU to an OUTPUT DEVICE. These results are transferred from the output storage area onto an output medium, such as a floppy disk, hard drive, video display, printer, and so on.

By now, you should have an idea of the functions performed by a CPU. It is the CPU that executes stored programs and does all of the processing and manipulating of data. The input and output (I/O) devices simply aid the computer by sending and receiving data and programs.

COMPUTER SYSTEM HARDWARE

Computer system hardware includes the CPU and its associated input and output devices. Input and output devices, separate from the CPU itself, are called peripheral equipment. The CPU communicates with each peripheral device through input and output channels. To operate an electronic-imaging workstation, you must have a general understanding of CPU primary and secondary storage, peripheral devices, input and output channels, and modems.

CPU PRIMARY AND SECONDARY STORAGE

The CPU contains circuits that control and execute instructions by using some type of MEMORY. Memory is referred to by size, such as 16K, 32K, 64K, and so on. The "K" represents the value of 1,000. Therefore 16,000 is 16K.

Semiconductor memory consists of hundreds of thousands of tiny electronic circuits etched on a silicon chip. Each of these electronic circuits is called a BIT CELL and can be in either an OFF or ON state to represent a 0 or 1 bit. This state depends on whether or not current is flowing in that cell. Another name used for semiconductor memory chips is integrated circuits (ICs). Developments in technology have led to large-scale integration (LSI) that allows more and more circuits to be squeezed onto the same silicon chip.

Some of the advantages of semiconductor storage are fast internal processing speeds, high reliability, low power consumption, high density (many circuits), and low cost. However, there is a drawback to this type of storage. It may be VOLATILE, which means it requires a constant power source. When the power for your system fails and you have no backup power supply, all of the stored data is lost.

Primary Storage

Two classifications of primary storage with which you should become familiar are read-only memory (ROM) and random-access memory (RAM).

READ-ONLY MEMORY (ROM).—In computers, it is useful to have instructions that are used often, permanently stored inside the computer. ROM enables us to do this without loosing the programs and data when the computer is powered down. Only the computer manufacturer can provide these programs in ROM; once done, you cannot change it. Consequently, you cannot put any of your own data or programs in ROM. Many complex functions, such as translators for high-level languages, and operating systems are placed in ROM memory.

Since these instructions are hardwired, they can be performed quickly and accurately. Another advantage of ROM is that your imaging facility can order programs tailored for its specific needs and have them installed permanently in ROM. Such programs are called microprograms or firmware.

RANDOM-ACCESS MEMORY (RAM).—RAM is another type of memory found inside computers. It may be compared to a chalkboard on which you can scribble down notes, read them, and erase them when finished. In the computer, RAM is the working memory. Data can be read (retrieved) or written (stored) in RAM by providing the computer with an address location where the data is stored or where you want it to be stored. When the data is no longer requited, you may simply write over it. Thus you can use the storage location again for something else.

Secondary Storage

Secondary storage, or auxiliary storage, is memory external to the main body of the computer (CPU) where programs and data can be stored for future use. When the computer is ready to use these programs, the data is read into primary storage. Secondary storage media extends the storage capabilities of the computer system. Secondary storage is required for two reasons. First, the working memory of the CPU is limited in size and cannot always hold the amount of data required. Second, data and programs in secondary programs do not disappear when the power is turned off. Secondary storage is nonvolatile memory. This information is lost only when you erase it. Magnetic disks are the most common type of secondary storage. They may be either floppy disks or hard disks (hard drives).

PERIPHERAL DEVICES

Peripheral devices include all the input and output devices used with a computer system. When these devices are under control of the CPU, they are said to be on line. When they perform their function independently, not under direct control of the CPU, they are said to be off line. The following peripheral devices are used commonly for input and output. Those that perform only input are marked (I), those that perform only output are marked (O), and those that perform both input and output are marked (I/O).

Optical Character Reader (I)

An optical character reader reads printed data (characters) and translates it to machine code.

Keyboard (I)

The keyboard is used by a computer operator to communicate with a computer system.

Mouse (I)

A small hand-held device used by a computer operator for positioning the cursor, making freehand sketches, or selecting items from menus on a screen. When the mouse is rolled across the surface of the desk, the cursor moves a corresponding distance on the screen.

Scanner (I)

A means of converting hand-drawn art or photographs into digital form.

CD-ROM Drive (I)

CD-ROM (compact disk-read only memory) technology is similar to audio disks, except it includes routines for detection and correction of data errors. A CD-ROM drive may be internally or externally installed. It holds a vast amount of information that makes it valuable to store digital images. Once recorded, information on CD-ROM cannot be erased or changed, but it can be read many times. The expression *Write Once, Read Many* (WORM) describes this type of technology.

Magnetic-Tape Unit (I/O)

The magnetic-tape unit moves magnetic tape across read-write heads that actually read and write the information. Data is recorded sequentially in the form of magnetic spots along the entire length of the tape.

Magnetic-Disk Drive Unit (I/O)

The magnetic disk drive unit is a storage device that reads and writes information on the magnetized surfaces of rotating disks. The disks are made of thin metal, coated on each side so data can be recorded in the form of magnetized spots. As the disks spin around like a music record, characters can be stored on them or retrieved from them in a random (direct) manner. Accessing data directly has several advantages over accessing data stored sequentially. It provides fast immediate access to specific data. You can direct the disk drive to read at any point. Magnetic disk drives come in two types: hard drives and floppy drives. Magnetic disk drives are in computer systems and electronic cameras. Floppy disks come in several sizes, ranging from 3 to 8 inches in diameter; the 3 1/2-inch diskette is most common.

Optical Disk Drive (I/O)

A drive used with a form of data storage in which a laser records data on a disk that can be read with a lower-power laser pickup. Three types of optical disks are used: Read Only (RO), Write Once, Read Many (WORM), and erasable. Two types of erasable disks are used: Thermo Magneto Optical (TMO) and Phase Change (PC).

Printer (O)

The printer is a widely used output device that expresses characters, graphics, drawings, or photographs on hardcopy (paper or film). A large range of printers is available. Printers are discussed in more detail later in this chapter.

Monitor (O)

The monitor is similar to a television screen. It allows you to see the program or data.

INPUT/OUTPUT CHANNELS

Input/output (I/O) channels provide a means of communication between the CPU and peripheral devices. This is accomplished by electrical cables that carry both data and control information between the computer and the peripheral devices.

Signals are transmitted and received through a cable that connects the CPU to an on-line device. This cable provides a path (channel) for the signal to travel. Signals for both monitoring and data are transmitted by way of I/O channels. These I/O channels may be used specifically for data input, data output, or data input and output. On desktop computers, the I/O channels are referred to as communication ports.

Types of Channels

Channels, both input and output, may be either simplex or duplex. A simplex channel is only capable of communication in one direction. When a peripheral device, such as a mouse, is connected to a simplex circuit, it is only capable of transmitting data. Simplex circuits are seldom used because a return path is generally required for acknowledgment, control information, or error message.

Duplex channels provide two paths for the transmission of data. One path is for sending, and one is for receiving data.

Data Transmission Methods

Data may be transmitted over a channel in one of two ways, either in the serial or the parallel mode.

SERIAL MODE.—In serial mode (transmission), three wires are required: one to transmit data, one to receive data, and one for a ground. The data is sent or received in the form of bits, one alter another in a series, as shown in figure 3-2. This type of transmission is desirable whenever a computer system is linked to outside peripherals over a long distance, such as remote terminals.

PARALLEL MODE.—In parallel mode (transmission), the data bits are all sent or received simultaneously. Parallel transmission requires nine or ten wires to connect the computer to the peripheral device (fig. 3-2). Seven or eight lines are required for data bits, one or two lines for “handshake” purposes, and one line for a ground. The handshaking signals communicate information back and forth between the peripheral devices and the computer. This information lets the peripheral know when the computer is ready to accept another character and vice versa. This type of transmission is useful for fast data transfer. The principal drawback is the computer must not be located relatively close to the peripheral device.

MODEMS

When data is transmitted directly to the computer over long distances, it is necessary to add two other devices, one at each end. These devices are called modems. The word *modem* is an acronym for MOdulator-DEModulator. A modem converts the digital signal produced by a computer to asuitable audio signal for transmission over communication lines (I/O channels). The modem at the other end of the line reconverts the audio signal back to a digital signal before sending it to the CPU. If this conversion (digital to audio) was not carried out, the digital signal would degenerate during transmission and become garbled. Modems are commonly used to send and receive data over telephone lines, making them a very valuable tool for imaging facilities.

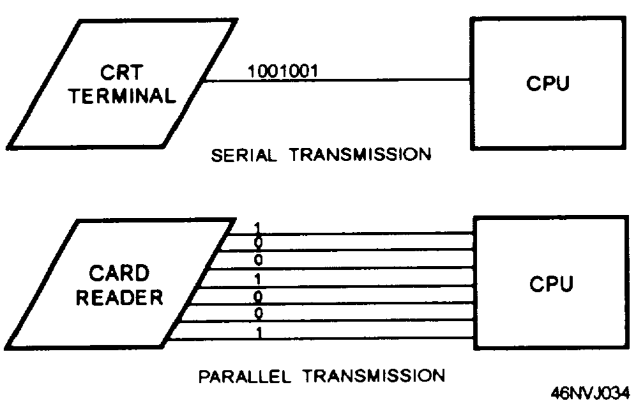

Figure 3-2.—Serial and parallel data transmission.

COMPUTER SYSTEM SOFTWARE

Software plays an important role in computer operations. Without software, a computer could not perform simple addition. It is the software that makes everything happen. "Software" may be defined as all the stored programs and routines (operating aids) required to use the capabilities of a computer system fully. Basically, two types of software are used: systems software and applications software.

SYSTEMS SOFTWARE

Systems software is often referred to as systems programs. Systems software consists of supervisory and support programs designed to coordinate the capabilities of the computer itself. These include programs, such as operating systems, assemblers and compilers, and utilities.

Operating Systems

An operating system is a collection of many programs used by the computer to manage resources and operations. These programs control the execution of other programs. They schedule, assign resources, monitor, and control the work of the computer. These actions are carried out without human intervention.

Assemblers and Compilers

Both assemblers and compilers are language translators. They are designed for specific machines and specific languages. They translate computer programs written in programming language into machine language. A language translator for an assembly language is called an assembler program. Most high-level language translators are compiler programs. These translators are designed to convert artificial languages used by programmers into machine-usable code after it is entered into the computer.

Utility Programs

Utility programs perform tasks, such as sorting, merging, and transferring data, from one I/O device to another. They may be separate programs, or they may be included in an operating system to help the user perform these tasks. Text editors may also be included in an operating system so the user can enter, add, delete, or change program statements; debug routines may also be included to help the user locate errors.

APPLICATIONS SOFTWARE

Applications are those particular programs designed to solve individual user problems. These programs can be written by you, the user of a computer system, developed by a central design agency, or they can be purchased from a software firm. Numerous types of applications programs are written. They range from games to word processing and electronic imaging.

ELECTRONIC IMAGE

When discussing electronic images, you must become familiar with the term pixel. The word *pixel* means picture element. A pixel is the smallest picture element that a peripheral device can display on screen. It is these individual elements that construct the image. The quality of an electronic image is determined by the pixels of the image—the more pixels per image, the greater the quality of the photograph.

A pixel is not an absolute unit, such as a millimeter. A pixel depends on other factors to determine its resolution. The image resolution depends on the number of pixels in a specific area. For example, a 1/2-inch square area containing 270,000 pixels has better resolution than a 1-inch area having the same number of pixels. However, resolution is not based solely on the number of pixels.

The resolution of electronic images depends on the size and the total number of individual pixels used to depict a single image. Each pixel can contain only one color or shade of gray. The smaller the pixels (more pixels per image), the closer the image can be viewed before the individual pixels are seen. Likewise, larger pixels may be objectionable. By increasing the number of pixels, you obtain finer detail.

When thinking in terms of resolution, you cannot compare pixels to the grain in film. Film resolution is not directly comparable to electronic-imaging resolution. Additionally, different types of imaging hardware use different types of measurements. For example, some equipment describes resolution in pixels and other equipment describes resolution in dots per inch (dpi). Pixels and dpi are not directly related or interchangeable.

Another problem in terms of resolution is there are no established conversion standards for images captured on different forms. An example where nonstandardization may present a problem is when comparing images from an analog camera to the products from a digital camera or the image output from an electronic printer or a film recorder.

ELECTRONIC-IMAGING WORKSTATION

Electronic imaging involves more than simply taking a photograph with an electronic camera. Like conventional photography, exposing the film is not enough. After the image is captured on film, it must be processed before the image can be viewed as a positive transparency or as a negative image that must later be printed to provide a useable positive image.

Images that are generated electronically must also be processed, but the methods to make the image visible and useable are completely different. On an electronic-imaging workstation, your "darkroom" is a computer system. To operate an electronic-imaging workstation, you must have both hardware and software. There are basically five components in an electronic-imaging system; they are the following: some type of input, a computer platform and software, display, storage, and hardcopy output (fig. 3-3).

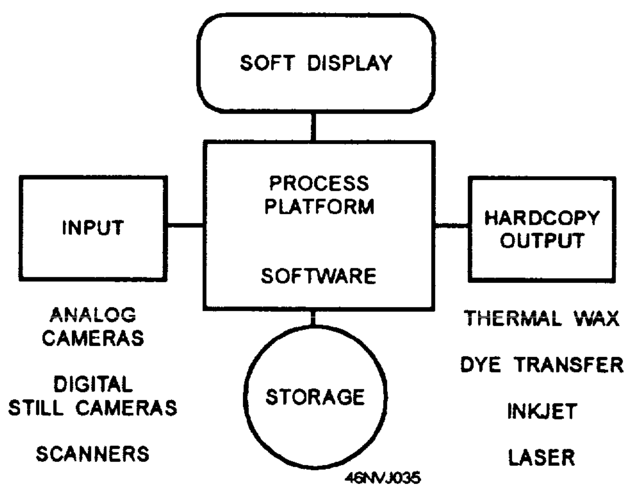

Figure 3-3.—Five basic components to an electronic-imaging system.

One major problem you will encounter when setting up an electronic-imaging station is interconnecting the various components that make up the imaging system. The technology in each component area is developing at a rapid rate. With the ever-increasing number of hardware components and software packages available on the market, setting up the links between the devices can become frustrating. Before choosing new components for a system, you must look carefully at each piece of new equipment to be sure it is compatible with the existing system.

INPUT

Several ways to acquire photographs electronically are used. You can obtain these photographs from digital or still-video cameras, or you can scan and digitize existing film and paper images.

Before a computer with the appropriate software can be used to modify or enhance an image, the image must be converted to digital values. Images that are imported from a still-video camera are in analog waveform. An analog waveform is a value that varies continuously over time (fig. 3-4). For an analog waveform to become a digital signal, both the value and the time must be changed into noncontinuous, numeric values of ones and zeros (fig. 3-5). The process used to determine time is called sampling. Sampling is done at equal increments of time. Conversion of continuous values into distinct values is called QUANTITIZING. The combined process is called analog-to-digital conversion (A/D conversion) or DIGITIZING.

The A/D conversion process is an approximation. When the sampling rate is low, a very inaccurate representation of the signal results. When the sampling rate is high, virtually an exact copy of the original signal is attained. When color images are digitized, the red, green, and blue information is handled as three separate sets of data to produce three sets of digital information.

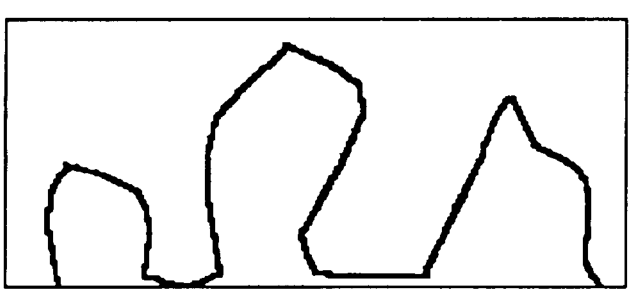

Figure 3-4.—Analog waveform.

0	1	1	0
1	0	0	1
1	1	0	0

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Figure 3-5.—Digital signal.

In this case, three A/D circuits are used and the encoding is done simultaneously.

When an image is digitized, a series of points are created. These points are called pixels. When the resolution of the display system is low, the individual pixels may be noticeable. This objectionable resolution is called pixelation.

Electronic Still Cameras

The advantage of using a digital or still-video camera is the image may be captured and inputed to the electronic-imaging workstation instantly. The features on these cameras are basically the same, and they are used in the same manner as conventional cameras. The features of conventional cameras and electronic cameras that are similar are as follows:

- The lenses may be fixed or interchangeable, depending on the camera.
- The lenses are identified by f/stops and focal length.
- The focusing may be fixed, automatic, or manual, depending on the camera.
- The range of shutter speeds is similar.
- The flash may be built-in or have a dedicated hot shoe.

Each electronic camera has an image sensor. The image sensor, called the "charge-coupled device" (CCD), is the main component of an electronic camera. The CCD is rated in size, pixels, and ISO. The larger the CCD, the more pixels it can record, thus the higher the resolution. However, the resolution quality and the exposure range of an electronic camera is not as great as what can be achieved with film.

Electronic cameras use one of three devices to store images. These three devices are a 2-inch video floppy disk, a hard drive or Random-Access Memory (RAM), and an integrated circuit (IC) card or chip.

In the 198Os, the still-video camera was introduced in the Navy. The still-video camera uses a 2-inch video floppy disk capable of recording 50 or 25 images. The number of images that can be recorded on a floppy disk depends on whether the image is recorded in the field" or "frame" mode.

The FlELD MODE uses one track per image on the floppy disk and allows 50 images to be recorded on one disk. The field mode provides poorer resolution because there are less pixels per picture. The FRAME MODE uses two tracks per image and allows 25 images to be stored on one floppy disk. The frame mode provides higher quality because more pixels per image are recorded.

Still-video cameras use an analog signal to record the images. This variable waveform represents density and colors that are created electronically by the intensity and the color of light striking an image sensor within the camera. This analog signal is the same type of signal used to record most motion-video images. It is also the same type of signal used in conventional television. Many still-video cameras have a playback capability and may be connected directly to a television monitor to view the images.

An analog signal records the lowest resolution of the electronic cameras, thus using the least amount of memory per image. Most still-video cameras have a limited resolution of approximately 380,000 pixels.

A still-video camera used by the Navy is the Sony Pro Mavica MVC-5000. This camera has three CCD chips that are used as the image pickup device and the high-band format to improve resolution.

An important factor to remember is that a still-video camera is an analog system, not a digital system. The format and configuration of a still-video floppy disk is different than that of a computer system, which is digital. By using the appropriate hardware and software, you must convert an image captured on a still-video camera from analog to digital format before it can be modified or printed in a digital-imaging system.

Still-Digital Cameras

A still-digital camera is superior to a still-video camera. As the name implies, a still-digital camera records an image in digital format. This digital format uses the binary system of "0s and 1s." The combination of these digits represents densities and colors created electronically by the intensity and the color of light striking an image sensor within the camera.

A digital image has a much higher resolution than an analog image. This higher resolution provides more pixels per image, but it also requires much more memory per image. Digital cameras use an IC card or chip and RAM or a hard drive. The RAM is built permanently into the camera and must be downloaded to another storage device. This storage device is an internal or external hard drive. This hard drive is similar to the hard drive found in personal computers. Kodak's Digital Camera System (DCS) uses a hard drive to store images.

The Kodak DCS still-digital camera combines a Nikon F-3 body and a standard lens with a digital-image back to capture high-resolution color or black-and-white images. The Nikon body operates similar to a camera with conventional film. The major difference between the Nikon being used with film compared to the DCS back is that the image area of the DCS is only one half of the size of a 35mm-film frame. This change in image area affects the effective focal length. For example, a conventional 35mm lens becomes a 70mm lens with the DCS. The Nikon F-3 functions, aperture settings, shutter speeds, and light metering operate the same as with film. Three major components that make up the Kodak DCS are as follows: an electronic back, a camera winder, and a digital storage unit.

Kodak's DCS models have a digital-image back that contains a 1,280 by 1,024 pixel CCD imager. This means the CCD is capable of recording about 1.3 million pixels. The color back equates to film speeds of 200,400, and 800. The monochrome back equates to film speeds of 400, 800, 1600, and 3200.

With a winder (spooler), you can shoot up to 2.5 images per second. The system has a standard 6 megabyte (Mb) buffer that can store six images in one burst. Thus it is possible to shoot faster than the images are stored.

The camera body of the DCS 100 is tethered to a Digital Storage Unit (DSU) that contains a hard drive. The 200Mb hard drive can store 158 uncompressed images or about 600 compressed images. The DSU also has a key pad for system control and a 4-inch monochrome monitor so you can view the images immediately.

The Kodak DCS 200 is a modified Nikon 8008 equipped with a Kodak DCS 200 camera back (fig. 3-6). The DCS 200 is capable of 1.54 million pixels of resolution. It also has an internal hard drive that can store up to 50 images. A small "hitchhiker" 40Mb hard drive is also available. This 40Mb hard drive plugs directly into a small computer system interface (SCSI) port on the camera for additional image storage. The SCSI is pronounced SCUH-zee.

The advantages of the Kodak DCS 200 over the Kodak DCS are higher resolution and portability. It is more portable than the DCS because it has a built-in hard drive. The disadvantages of the DCS 200 are it stores less images than the DCS 100, and it has no built-in compression or transmission capabilities.

One of the biggest advantages of capturing an image digitally is the way the images can be processed. A digital image may be re-recorded without loss of image quality and the color and sharpness can be enhanced. This digital signal is identical to the signal used in a computer; thus, by using the proper interface, the signal from a digital-still camera can be imported directly into a computer.

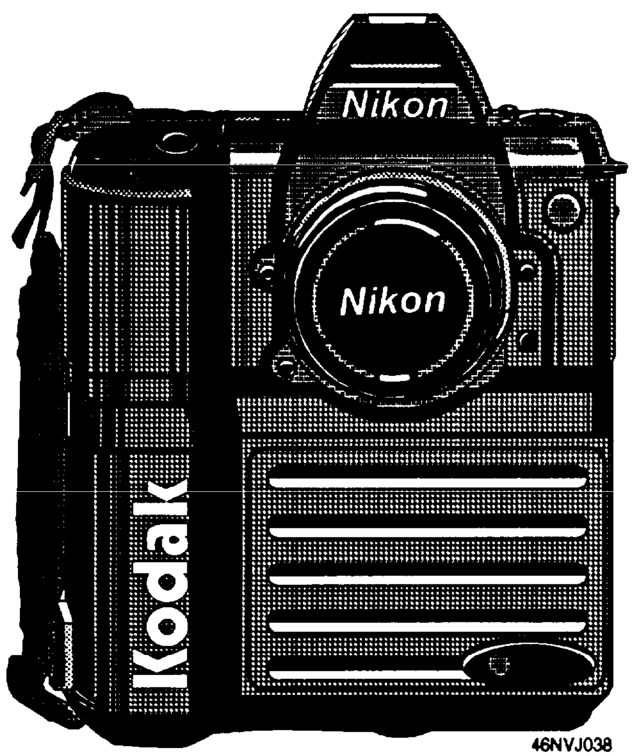

FIgure 3-6.—Kodak DCS 200.

Scanners

Film transparencies, negatives, and prints are sources of images that can be produced and edited electronically. Scanners can create digitized images with extremely high resolution. Scanners are also capable of providing resolution equal to the original negative or print.

Scanners come in three categories: rotary drum, flatbed, and film. Rotary-drum scanners provide the highest quality for converting images from film or prints, but they are very expensive. Rotary-drum scanners are capable of producing resolution ranging from 1,000 to 5,000 dpi. When a rotary-drum scanner is used, the film or photograph is placed on the surface of a drum that rotates while the original is scanned by a single beam of light. The beam of light and the speed of the drum can be adjusted to control the amount of resolution desired.

Scanners that use charge-coupled devices (CCDs) provide excellent quality. They are used in many Navy imaging facilities. Scanners operate similar to a photocopy machine. A CCD chip with a row of light receptors scans a photograph or negative and changes the colors or shades of gray (analog signal) into digital values.

Full-color scanners have three rows of CCDs: one for red, one for green, and one for blue. This tricolor array permits full-color scanning with a single pass of the scanning head. The number of elements in the CCD array determines the resolution of the images being scanned. For example, an 8.5-inch linear array with 2,540 elements has approximately 300 elements per inch. This array can produce a digitized image with a resolution of 300 dots per inch (dpi). Most standard desktop scanners operate in the 300- to 400-dpi range. When an image is scanned on a scanner that produces 1,000 to 5,000 dpi, a higher resolution results, but the scan time and file size also increase. Generally, the resolution required for a scanned image is limited to the output of the imaging system.

A flatbed scanner is used for scanning photographs and artwork. Some flatbed scanners are also capable of scanning transparencies and color negatives. The resolution of flatbed scanners range from 200 to 1,200 dpi. Unlike a rotary-drum scanner, a flatbed scanner scans an entire line at one time with a linear CCD array.

Film scanners are used to scan negatives and transparencies. Many of these scanners come with software packages that allow you to crop the image and make color corrections before the image is scanned into a digital file. By making these adjustments before scanning an image, you can save time and file size. Scanners are produced by a number of manufacturers. Scanners used in Navy imaging facilities are produced by Nikon and Kodak (fig. 3-7).

Once an image is converted to digital format, the data is passed from the scanner to the computer through an interface. Because of the enormous amount of data involved in electronic imaging, information is passed through a SCSI.

A SCSI is a special kind of parallel interface that allows for faster data transmission. The SCSI interface permits a number of peripheral devices to be connected to the computer through a single SCSI port. This is accomplished by chaining the devices together with a SCSI cable. The last device in the chain must have a special adapter, known as a terminator. Some devices have built-in terminators.

Each device in the SCSI chain is identified by a unique identification number. When the scanner is connected, you must verify that none of the peripherals have the same identification number. These identification numbers may be changed by using either dipswitch settings or software.

The scanner uses two programs to operate. One program is a paint program to manipulate the image once it is in the computer. The second program is a driver that acts as a translator between the scanner and the paint program. Once the image is digitized,

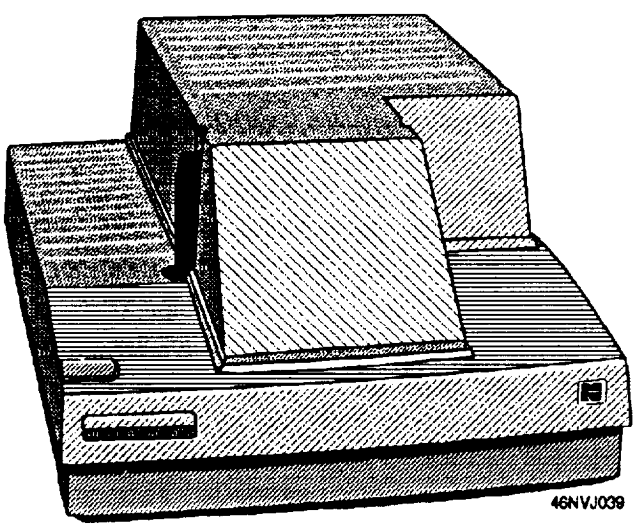

Figure 3-7.—Kodak 7720 thermal-dye transfer printer.

limitless modifications and enhancements can be made to the image.

Because a scanner scans at such high resolution, the end file is quite large. Thus a considerable amount of storage space is required. It is common for a 24-bit color image to require 20 to 25 megabytes of storage.

COMPUTER PLATFORM AND SOFTWARE

The entire electronic workstation is designed around a computer (fig. 3-8). There are three major computer platforms in use for digital photography—the Apple Macintosh, PCs (IBM or compatibles), and Unix-based machines. The most popular computer for digital imaging is the Apple Macintosh. However, PCs and IBM compatibles are also used for digital imaging. They are becoming more popular in the digital-imaging marketplace. Unix-based workstations are used for science-oriented operations and high-volume publishing of books and technical manuals. Therefore, Unix-based machines are not commonly found in Navy imaging facilities.

Regardless of whether you are using an IBM compatible or a Macintosh platform for electronic imaging, the applications are basically the same. Specific computer systems are not covered in this training manual. Only the principles that apply to electronic imaging are discussed.

Computer Configurations

As a guideline, the computer must have a minimum of 8Mb of RAM. For work efficiency, you need at least 32Mb of RAM. Storage may also become a problem because of the large-size file of color digital images. A high-resolution scanned image can require 250 megabytes or more of memory. A hard drive in excess of 600Mb is not uncommon for an electronic-imaging workstation.

The computer system must also have sufficient expansion slots to install interface cards for add-on peripherals, such as scanners, film recorders, and printers. A number of interface cards are available for both Macintosh and PCs that convert analog images to digital format.

Software

Like computer platforms, a vast number of software packages are available for scanning and modifying images. Computer software (programs) makes it possible for you to communicate with the hardware.

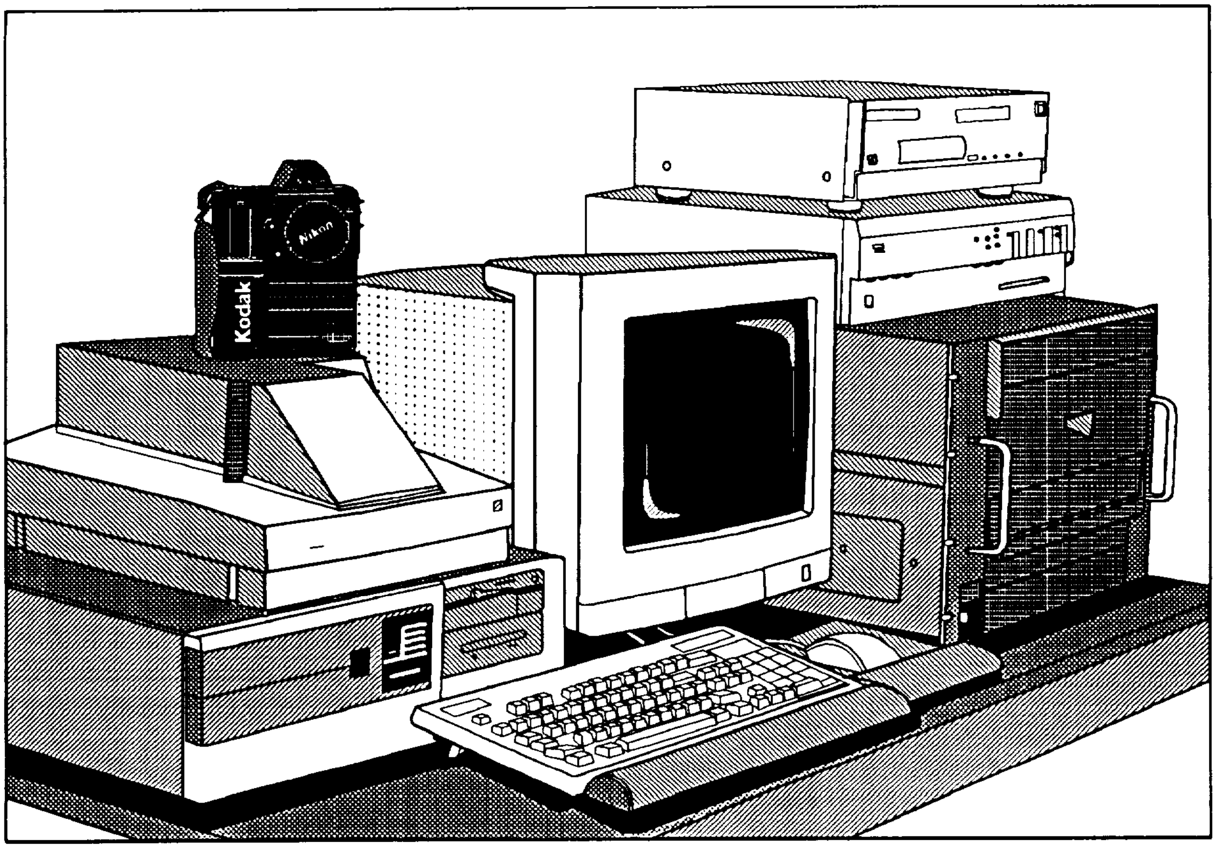

Figure 3-8.—Electronic imaging workstation centered around an AT computer.

These software packages are capable of doing more than you could accomplish in a conventional darkroom; they do it much quicker.

Advancements in the development of software packages have made it possible to transform computer imaging from minicomputers or mainframe computers to desktop models. Because software is continually being improved and updated, the application of specific computer software is not addressed in this chapter. Software packages are used to modify and enhance images and to control input and output devices.

DISPLAYS

Most of the computer color monitors available for desktop computers have far less resolution than a digital photograph. A number of graphic boards are available for computers that can produce Super VGA resolution of more than 1,000 by 1,000 pixels on cathode-ray tube (CRT) color displays. A high-resolution, noninterlaced monitor and a 24-bit video card are essential viewing images. A 24bit video card allows for 16.8 million colors to be displayed.

Graphic images displayed on a computer monitor are bit-mapped images. Bit-mapped images are produced by a pattern of dots. Bit-mapped images are sometimes called "pixel-oriented," "raster," or "paint" images. At high resolutions, the individual dots are not discernable.

When you are working on enhancement, modifications, and page makeup of digital images, it is important for you to view what you have done. Therefore, a calibrated color monitor is important so you can see the images or “soft proofing” before you print the images. Monitors for electronic imaging use the additive system. They combine red, green, and blue and add it to the black surface of the screen to create colors.

Monitor quality depends on screen resolution. The finer the pitch of the screen, the sharper the image. The PITCH of the screen is the size of a single pixel. On color CRT screens, a single pixel is composed of three phosphor dots: red, blue, and green. These phosphor dots are struck by an electron gun through a screen or mask. The resolution of the CRT depends on the size of the holes in the mask. The holes in the mask are necessary to direct the electron beam so it strikes the correct phosphor dots as the electron gun scans the screen (fig. 3-9).

Color monitors are available from standard EGA levels to pixel levels of 2,048 by 2,048. The monitor that is selected for your imaging system must match the display card in the computer, since it is the display card that limits the resolution of the monitor.

DIGITAL-IMAGE FILE STORAGE

Color digital images take up an extremely large amount of memory when they are stored. Methods, such as optical media, have been developed to overcome this storage problem. Optical media is very suitable for storing digital photographs. Some examples of optical media include the following: Write Once, Read Many (WORM) disks, erasable optical disks, and optical memory cards. An example of nonerasable memory is the Kodak Photo CD; this CD allows high-quality color images to be stored for archival and retrieval purposes.

One Kodak Photo CD can store up to 650 megabytes. This equates to 100 high-resolution, color digital images when stored in compressed form. These images are stored at five different resolution levels, ranging from 128 by 192 pixels for a proof, or thumbnail sketch, to a high resolution 2,084 by 3,072 pixels (compressed) full-color image. These images can be imported using photo software packages, then they can be manipulated, printed, or placed in various layout applications.

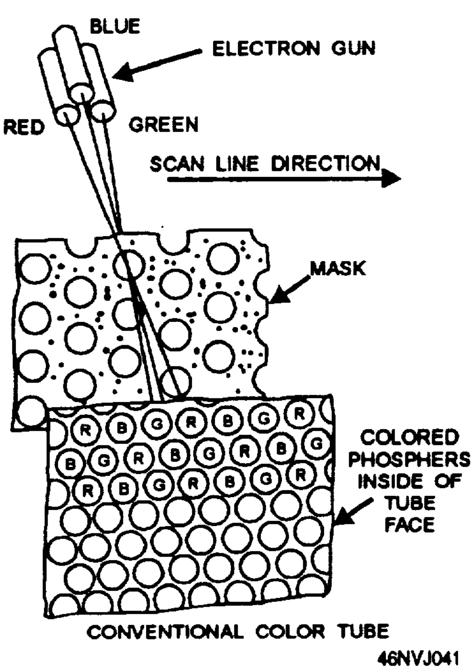

Figure 3-9.—Cross section of a CRT.

Image compression makes it possible to take a large color-image file and reduce its size. This reduces the amount of memory required to store it or decreases the time required to transmit it. Compression can reduce the amount of memory needed by a factor from five to one hundred. Various compression-decompression chips, add-on boards, and software are available in the commercial market.

Image compression is made possible because in a typical digitized image, the same information appears several times. For example, areas of the same color in different parts of the image or straight lines contain the same information. This duplication of information values, or REDUNDANCY, can be identified in three types as follows:

- Spatial redundancy. This results from dependence among neighboring pixel values.
- Spectral redundancy. This results from an association of color (RGB) planes.
- Temporal redundancy. This results from a correlation between different frames in a sequence of images.

The most common compression program has been formed by the Joint Photographic Experts Group (JPEG). The technique used in JPEG compression allows the user to select the compression ratio.

High-compression ratios generally result in low image quality. This low image quality is a result of avoiding the risk of losing data as the image compression ratio is increased. The amount of image compression depends on the amount of redundancy that exists in an image. When a compressed image is reconstructed (uncompressed) and the pixel values are identical to the original image, the compression is known as lossless. When discrepancies occur between the original and the reconstructed image, the compression is called lossy. Lossless compressions can be achieved with compression ratios of up to 5 to 1. Files that are compressed may be identified by the file extension ".JPG."

HARDCOPY OUTPUT

A number of methods for making digital photographs are used. Some of these technologies include the thermal-dye transfer, inkjet, thermal-wax transfer, and printers that use silver-halide photographic paper to produce digital images. Color copiers can also be used to print digital images to provide suitable quality at high speed and relatively low cost. Like most electronic equipment, a large variety of printers are available on the market. They range from hundreds to thousands of dollars.

Most printers used for making color prints from digital images use three colors: cyan, yellow, and magenta (CYM). Some printers match the full cyan, yellow, magenta, and black (CY MK) process.

Located between the printer and the computer is a RASTER IMAGE PROCESSOR (RIP) or a PAGE DESCRIPTION LANGUAGE (PDL). This is a software and hardware configuration that permits information to flow to the printer so the printer knows where to place the image on the paper.

Thermal-Dye Transfer Printers

Thermal-dye transfer printers are often called dye-sublimation or dye-diffusion thermal-transfer printers. This system provides high quality and an environmentally safe method of transferring images to print and transparency materials without using chemicals (fig. 3-10).

The thermal-dye transfer printing process uses thousands of tiny heating elements that come in contact with "donor ribbons." Each donor ribbon releases a gaseous color dye when heated. Three-color printers have cyan, magenta, and yellow ribbons (CMY); four-color printers also include a separate black ribbon (CMYK). The amount of heat from each element controls the amount of dye being transferred to the print material. The blend of the gaseous colors creates a continuous-tone image.

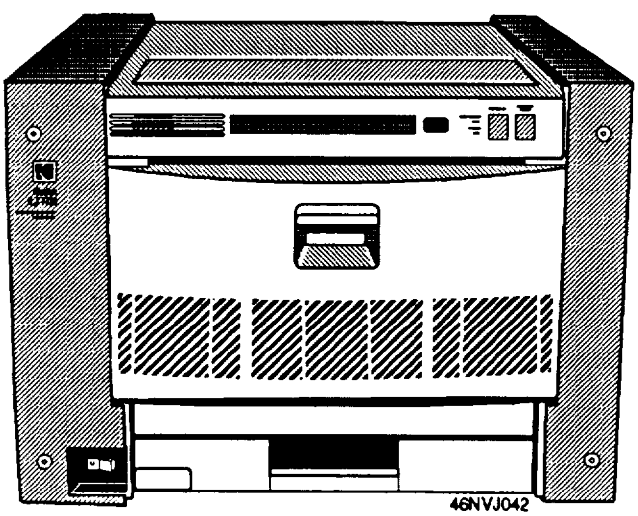

Figure 3-10.—Kodak 7720 thermal-dye transfer printer.

The quality of a thermal-dye transfer print resembles a print made from conventional silver-halide paper. The resolution of thermal-dye transfer printers ranges from 160 to 300 dpi. Resolution is limited by the thermal printing head. Thermal-dye transfer printers can produce prints from 3.5 by 5 inches up to 14 by 17 inches.

Inkjet Printers

Inkjet printers are used in a variety of situations from newsprint to transparency materials. Inkjet printers use cyan, magenta, yellow, or black streams of ink to produce images. Inkjet printers today are capable of producing excellent continuous-tone color prints by using variable-size dots of ink that are precisely controlled. Inkjet printers are nonimpact printers that use droplets of ink. As the head of the printer moves across the surface of the paper, it shoots a stream of tiny electrostatically charged ink drops at the paper.

Color Copiers

Color copiers were originally designed strictly for copying color originals. Today, however, color copiers have the added capability of copying transparencies and being connected directly to imaging workstations through an interface. This interface accepts digital signals to produce color photographs.

Color copiers are capable of producing prints with a true photographic appearance. One minor drawback to prints produced on color copiers is they are printed on plain, bond paper stock Color copiers use a laser device that fuses toner to paper to create the image.

Some color copiers, such as the Canon Color Laser Copier 500 (fig. 3-11), can be used as a flatbed scanner in addition to providing high-quality color images directly from computer files. The resolution of such color copiers is 400 dpi on standard copier paper.

Thermal-Wax Transfer Printers

Thermal-wax transfer printers operate on the same principle as thermal-dye transfer printers. Thermal-wax transfer printers use cyan, magenta, and yellow wax type of pigments instead of ink to produce images.

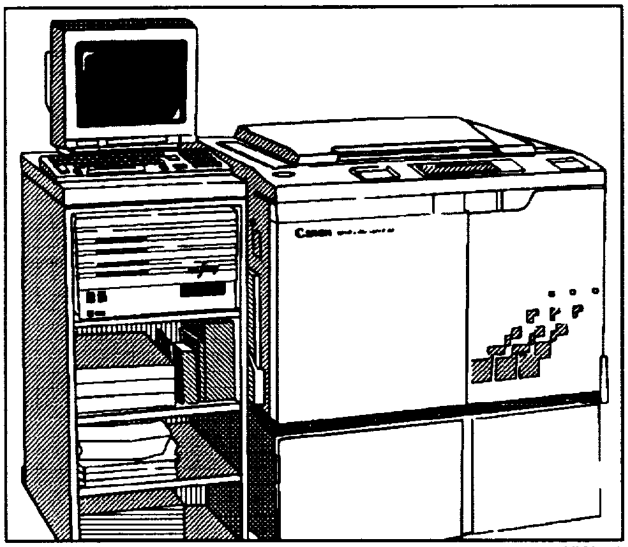

Figure 3-11.—Canon 500 color copier with the EFI Fiery controller.

Thermal-wax printers are designed to produce clean, bright colors; however, they have a limited range of colors because these printers are only capable of producing colors that are one-bit per color deep. These printers are relatively inexpensive and can produce large prints quickly.

EDITING DIGITAL IMAGES

To edit digital images, you must rely heavily on computer software. The software allows you to manipulate the image. You can crop, retouch, and change colors of the entire image or any section of the image. With the powerful software packages available, you can change the original image into something completely different by merging one digital image with another. The scope of the aesthetic and creative aspects of the final digital image is limitless.

Editing digital images involves using graphic-interface software. This type of software is much easier to learn than text-based software. There are two essential elements of graphic-interface software: MOUSE and a BIT-MAPPED DISPLAY. The mouse is a small hand-held device that must be connected by a cable to a computer. When you manipulate the mouse on a desktop, it causes the cursor to move on the screen of the computer monitor. This method allows you to move files, run programs, draw lines, and execute commands. You can accomplish this by moving the mouse to the appropriate location and "clicking" a button. A bit-mapped display is composed of tiny dots that am turned on or off individually; this allows the computer to show graphic images in addition to text. Bit-mapped displays are used in Apple application software and Microsoft "Windows" programs.

Graphical interfaces are easy to use because they provide a “point and click” approach to operating software. Files and software functions are displayed as small graphical icons (fig. 3-12). For example, an icon bearing the image of a folder may represent a file; or an icon bearing the image of a magnifying glass may allow you to zoom in on a portion of the screen. Graphical interfaces also use WINDOWS. A window can be compared to an open drawer (folder) of a file cabinet (hard drive). Windows are displayed as frames on the screen. These display different "files" in the "folder."

Two software packages used in Navy imaging facilities for electronic imaging are Adobe *Photoshop* and Aldus *PhotoStyler*. These software packages are not just photographic editing and enhancement tools but complete illustration programs. These two programs operate in the same manner. With "hands on" experience, you will soon become proficient.

Photoshop is available for both Macintosh and PC/windows platforms. *PhotoStyler* is designed for use in the PC windows environment only. Figure 3-13 shows some of the tools available in these two computer programs. As you can see, these two imaging software packages are very similar.

Although there are several software packages available for editing electronic images, they are all similar. These similarities are as follows: paint tools, selection tools, filters, and color correction.

PAINT TOOLS

Paint tools allow you to retouch or add selected colors to an image. The tools typically include a paintbrush that allows you to draw in a color or pattern, a paint bucket that allows you to pour a color or pattern into a selected section of an image, and a spray paint tool that provides you with an airbrush effect. These image-editing programs allow you to perform color correction and to change contrast and density of the image. Other common tools may include a pencil for adding or deleting pixels, a teardrop for softening edges, and a finger paint or smudging tool for smudging colors.

An interesting option in most image-editing programs is the cloning tool. To use the cloning tool, you first select the icon; then you must click the mouse

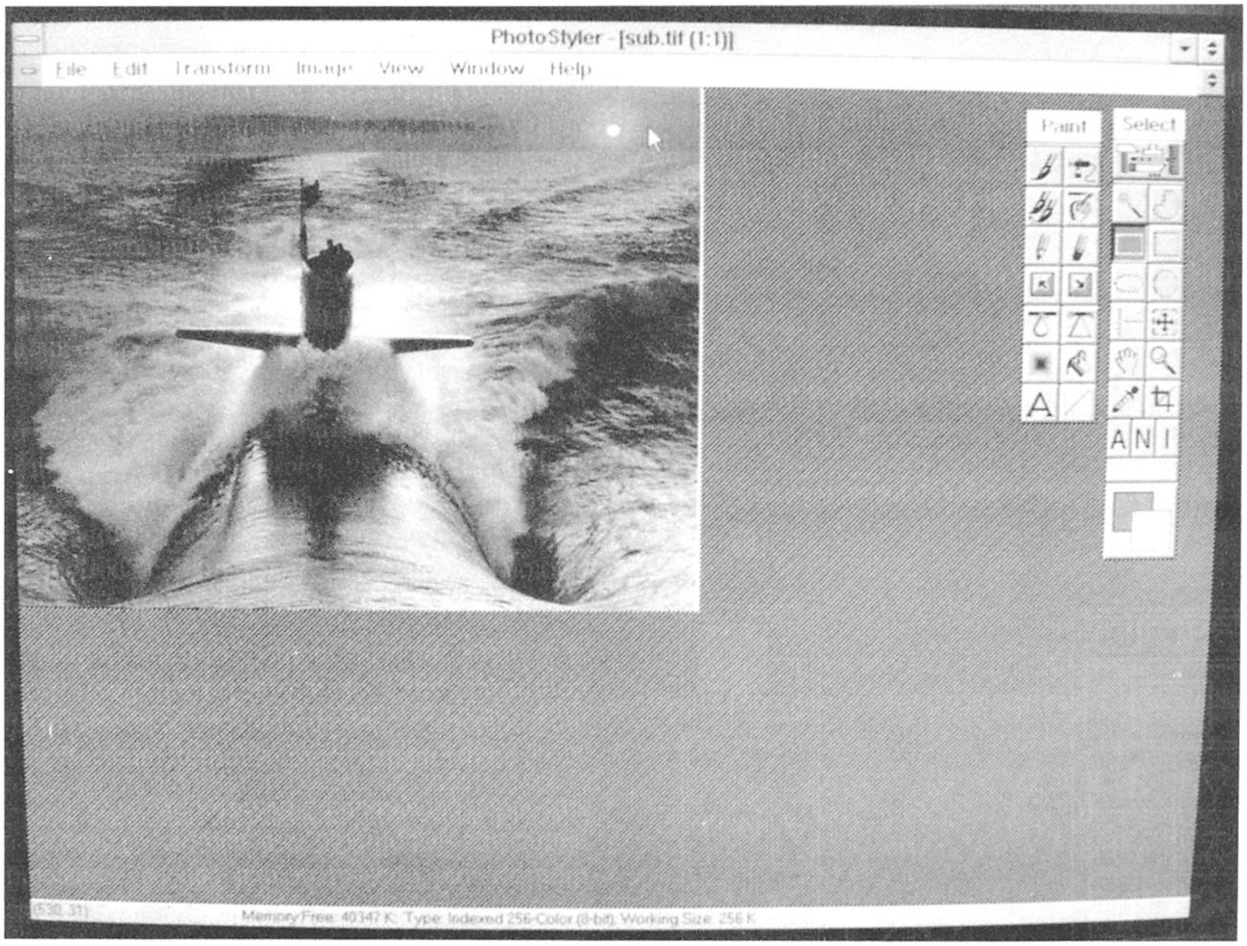

Figure 3-12.—Open file displayed on PhotoStyler palette.

button after moving the cursor to the portion of an image that you want to replicate. Now move the cursor to the part of the image where you want to "paint" the image that you selected (fig. 3-14). This cloning tool is particularly useful for removing dust spots, scratches, reflections, and so forth.

The imageediting software used by Navy imaging commands allows you to modify the way these tools function. You can change the size and shape of the brushes, soften the edges of the tools, and control the transparency of selected colors.

SELECTION TOOLS

Selection tools allow you to select portions of an image and to perform a variety of operations. When using *Photoshop* or *PhotoStyler*, you have a high degree of control in editing, retouching, or manipulating images. A rectangular tool allows you to select rectangular areas and a lasso tool allows you to select objects with irregular shapes. Another tool allows you to select a color from a portion of an image by clicking on it; you can clone it and replicate it elsewhere. By using these tools, you can add an aircraft formation to the image of an aircraft carrier. Then, using a blending tool, you can blend the two images smoothly. Other tools allow you to stretch or rotate images. Some programs have a magic wand tool that allows you to click inside an irregular-shaped object, and it isolates this object automatically (fig. 3-15).

FILTERS

The filter features provided in image-editing software control the image brightness and contrast as well as sharpen or soften selected portions of the image. Some programs provide a "mosaic" filter so you can convert a portion of the image into large-size pixel areas. You have probably seen this effect used for

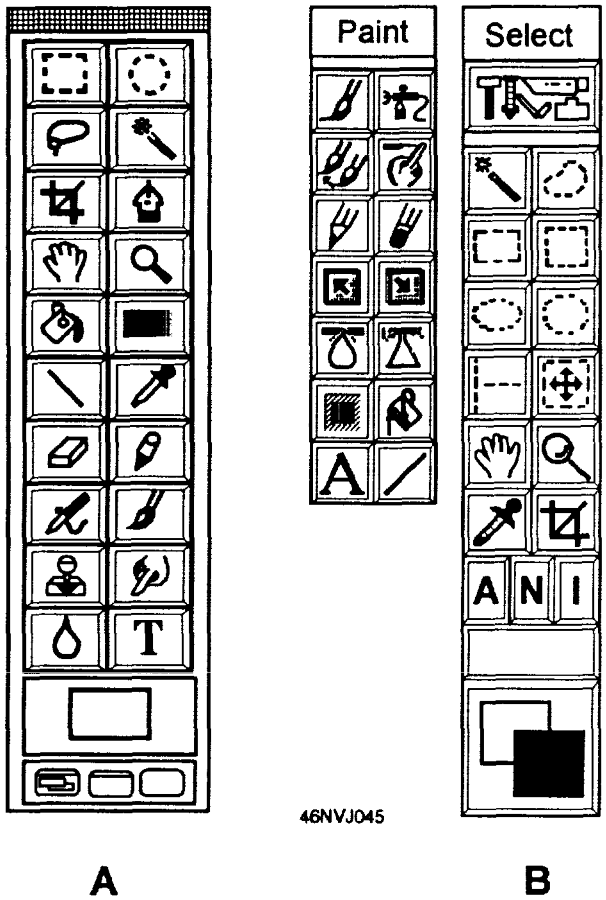

Figure 3-13.—Photoshop and PhotoStyler tools.

television interviews where people do not want their identity revealed.

COLOR CORRECTION

Imageediting programs also offer color correction and calibration features. These color correction features allow you to modify an image to get the best possible quality to a color printer or other output device (fig. 3-16). These color corrections are accomplished by using a gamma curve.

The gamma curve represents the pixel values in the original image on the horizontal axis. The corresponding values of the displayed image are represented on the vertical axis. Separate red, green, and blue lines may be displayed so you can modify each color independently. By increasing the slope, you can raise the contrast level; this forces most of the pixels toward the light and dark ends of the spectrum. By raising or lowering the entire line, you can adjust the brightness.

TRANSMITTING DIGITAL IMAGES

One of the biggest advantages of electronic imaging is time. After a photograph is taken, it can be transmitted anywhere in the world in a matter of seconds. This makes images available immediately. This immediacy is both critical and valuable to civilian media teams and military organizations. With electronic imaging, there is no film processing or printing. What you need to do is activate a transmitter and send it.

Several methods of transmitting electronic images are used. One method of transmitting the image is using the Sony Digital Information Handler with the Kodak DCS 100. The Sony Digital Information Handler is a digitizer and transceiver that can be connected to a phone line or uplinked to a satellite. This unit uses a still-video camera and 2-inch floppy disk.

Another method of transmitting images is by use of the Kodak DCS 200. This unit can be hooked to a laptop computer, such as a MacIntosh Powerbook, to accomplish the same methods of transmission.

Companies, such as Harris Corporation and Phototelesis Inc., have built rugged, portable image processing workstations that are compatible with standard U.S. Navy communication systems and encryption devices. These devices provide a secure means for transmitting tactical intelligence images worldwide.

One problem you may encounter when attempting to transmit images is locating a clear phone line or an available satellite. A clear phone line is necessary to ensure that a good image is transmitted.

Another factor you must consider when transmitting images is the amount of time you are tying up the circuit. The larger the file size, the longer it takes to transmit the file. It is good practice to compress files before transmission. When files are received at the other end, they can be decompressed without loosing quality.

You can see the major advantages of electronic imaging. Images that used to take days or even weeks to obtain can now be obtained in minutes.

ETHICS AND THE ELECTRONIC IMAGE

The adoption and popularity of electronic imaging raises important ethical questions. The altering of images has existed since the beginning of photography.

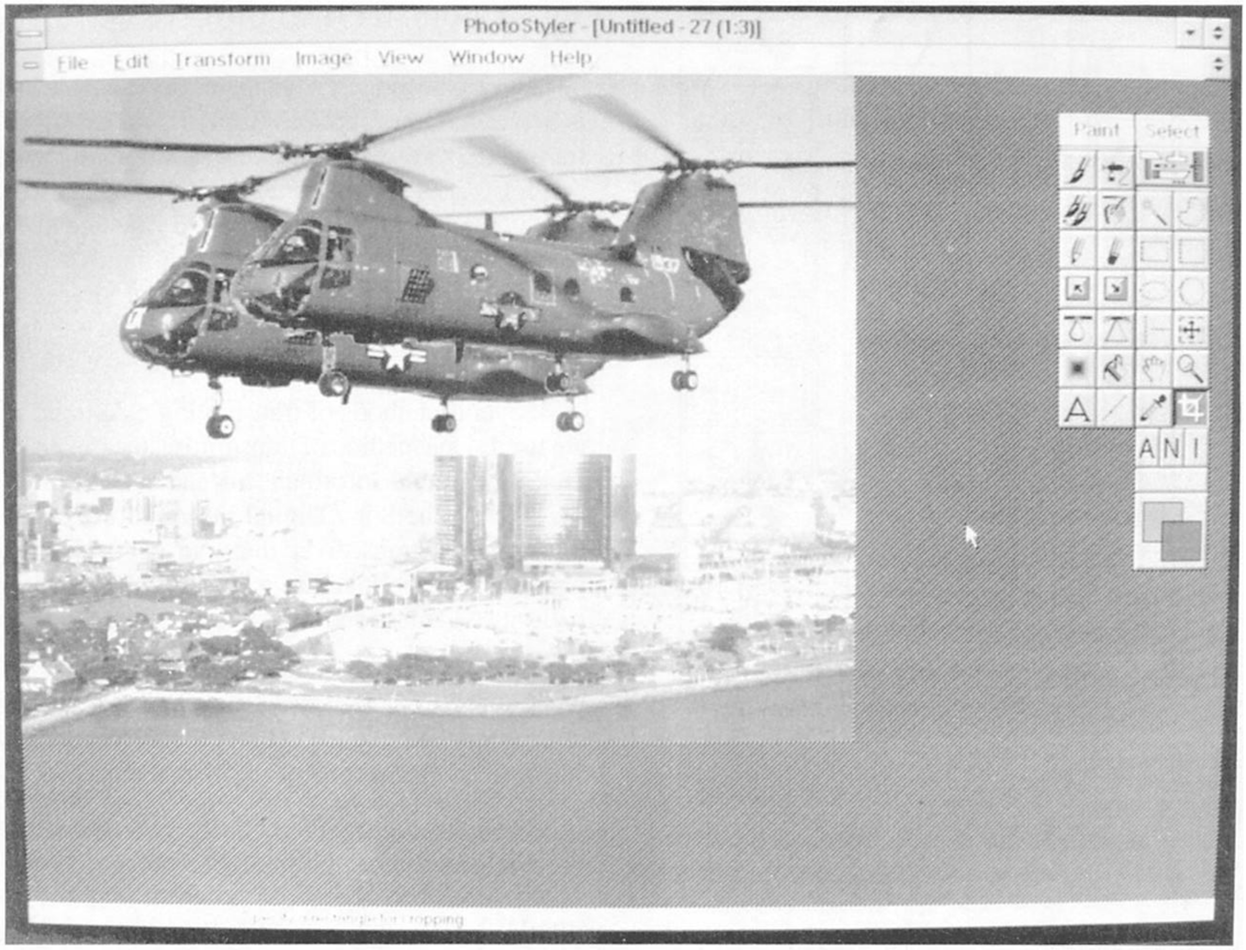

Figure 3-14.—The cloning device was used to replicate a helicopter in this image.

But, such manipulations have never been easy to achieve and were very time-consuming. However with electronic imaging, you can create images and manipulate images easily, completely, and it is virtually undetectable. Electronic information, unlike traditional photography, can be modified radically without loss of resolution or evidence that the information has been altered.

Official Navy images must be truthful. Most electronic images require some type of enhancement or manipulation, but you must not deceive the viewer when creating electronic images for official purposes. Some types of image manipulation are morally acceptable and others are not. You must have a clear understanding of what is considered deception.

"Deception" may be described as an intentional act to mislead someone to a false conclusion. Deception exists when a person is misled by an outright lie or by failing to provide a person with the relevant truth. When manipulation of an image creates a false depiction of reality or when manipulation of an image fails to disclose some relevant piece of reality, the manipulation is deceptive.

To help you determine whether an action on an electronic workstation is ethical, you should draw a distinction between image manipulation and image enhancement. The following two scenarios are provided to help you arrive at the difference between image manipulation and image enhancement.

1. An obviously overweight male LCDR comes into the portrait studio for a full-length photograph. This photograph is for use for a promotion package. It is neither acceptable nor ethical for you to manipulate this person's image by stretching and slimming his body or superimposing his head on an image of a physically fit body. Removing a reflection from his glasses is an acceptable enhancement since it does not change his overall natural appearance.

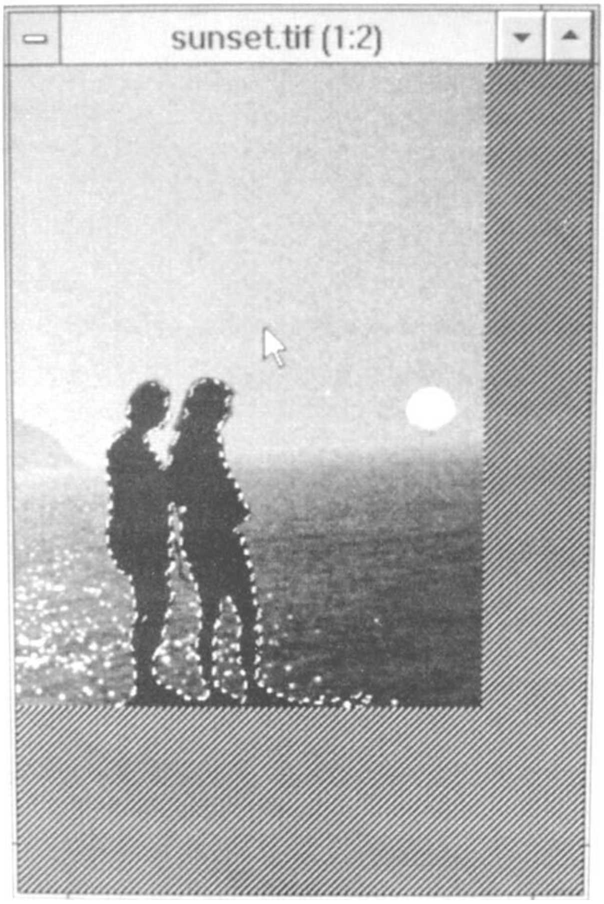

Figure 3-15.—Magic wand used in PhotoStyler to isolate the silhouette image.

2. You shoot a head-and-shoulder portrait of the new commanding officer. After pulling up the image on the monitor, you notice a smudge of lipstick on her teeth. It is acceptable and ethical for you to remove the lipstick from her teeth because this does not change her appearance. However, it is not ethical for you to straighten a crooked tooth because this changes her natural appearance.

Currently, official instructions and guidelines are nonexistent for electronic image enhancement or manlpulatlon. Therefore, it is important for you to have high, personal, and ethical standards. Unlike conventional silver-halide photography where photographic prints can be compared with the original negative, digital images can be retouched or changed with absolutely no evidence of modification.

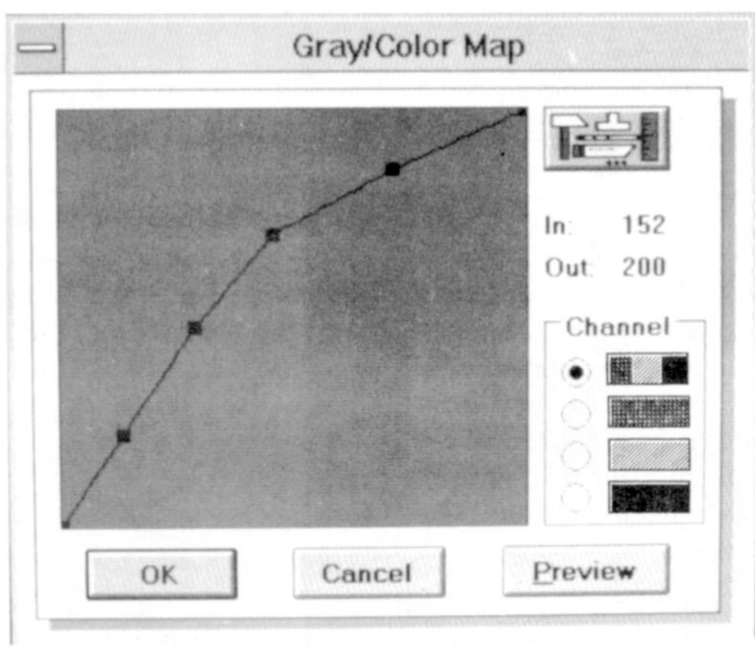

Figure 3-16.—Color correction tool used in PhotoStyler.